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SOVIET HARD ALLOYS

There are six basic groups of hard alloys, defined by methods of preparation: cast hard alloys of Stellite type, powder hard alloys, metalloceramic hard alloys, cast high-carbide hard alloys, tubular hard alloys, and electrode hard alloys.

Cast Hard Alloys of Stellite Type

Three alloys of this type are produced and widely used by USSR industry.

Stellite V-3K, wolfram-chromium-cobalt-base alloy, is very close, in chemical composition and physicomechanical properties, to the American Stellite Haynes No 6. The other two are iron-chromium-base, so-called Stellite-like, alloys Sormayt No 1 and Sormayt No 2.

Sormayt No 1 is a hypereutectic alloy which, in structure, approaches high-chromium stainless cast irons. Heat treatment practically does not affect this alloy (no significant changes in hardness).

Sormayt No 2 represents a hypoeutectic alloy differing from No 1 by the lower contents of alloying elements and carbon. It responds to heat treatment similarly as chromium tool steel, sharply increasing its hardness upon quenching. Annealing of Sormayt No 2 permits machining of hard-faced parts with ordinary cutting tools.

Chemical composition of cast hard alloys of the Stellite type is as follows:

	W	Cr	CO	C	Ni
V-3K	4-5	28-32	58-62	1-1.5	2 max
Sormayt No 1	-	25-31	-	2.5-3.3	3-5
Sormayt No 2	-	13.5-17.5	-	1.5-2	1.3-2.5

	Mn	Si	S and P	Fe	Others
V-3K	-	2.75 max	-	2 max	0.5
Sormayt No 1	1.5 max	2.8-4.2	0.08 max	Remainder	-
Sormayt No 2	1 max	1.5-2.2	0.07 max	Remainder	-

The following table presents the physicomechanical properties of cast hard alloys:

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Properties	V-3K	Sormayt No 1	Sormayt No 2
Rockwell hardness (A scale)			
In bar form	71-73	76-78	71-73
Hard facing deposit in two layers	71-73	75-77	70-73
The same after annealing	-	-	66-68
The same after hardening	-	-	76-79
Tensile strength in kg/sq mm	60-70	35	-
Bending strength in kg/sq mm	-	70	110
Compressive strength in kg/sq mm	-	165	-
Coefficient of linear expansion (20-900°C)	12.10^{-6}	12.10^{-6}	13.10^{-6}
Shrinkage on solidification, %	2.0	1.8	2.3
Melting point, °C	1275	1275	1300
Specific gravity	8.5	7.4	7.6

NOTE: The table gives average values for specimens cast into iron molds. These values may be considerably varied because of cooling conditions on solidification.

The resistance to chemical corrosion of Stellite-like alloys is somewhat lower than that of Stellite because of the considerable iron content. However these alloys are sufficiently stable against certain reagents, such as high-pressure steam, sulfuric acid, sea water, and others.

Electrical and thermal conductivities of cast hard alloys of the Stellite-type are approximately 1.5-2% of those for copper. Red hardness of Stellites is 700-800°C and of Sormayts, 500-600°C.

Cast Stellite-type alloys have a low coefficient of friction, 0.11 between two hard-faced surfaces. This is approximately only one half of the coefficient of dry friction for other metals or corresponds to sliding friction of metals under ordinary lubrication.

The high wear resistance of Stellite-type alloys makes them very essential metals for welding onto wearing parts and tools, increasing the service life of the latter from three to ten times.

Here, the comparative wear resistance of hard alloys and steels is given, determined for equal testing periods on a carborundum grinding wheel.

Type of Metal	Wear (mg/sq mm)
Vokar	0.4-0.8
Stalinit	1.5-2.5
Sormayt	2-3.5
Chromium electrodes	2.5-4
Manganese electrodes	2.5-4.5
Chrome-nickel steel, 5% Ni	6-7
Carbon steel, 0.5% C	10-15

Manufacture of cast Stellite-type alloys is not complicated. Initial products for making Stellites are metallic wolfram (or wastes of metallo-ceramic alloys), chrome, cobalt or nickel, activated charcoal, and flux (glass). Ferrochromium, ferromanganese, ferrosilicon, nickel, iron and cast-iron scrap, activated charcoal, and flux are used for smelting Sormayts. Melting is mostly conducted in high-frequency induction furnaces with an acid lining, a heat being entirely melted at 1,500-1,600°C. Casting is made into metal molds preheated to 400°C. Rods less than 5 mm in diameter are made by centrifugal pouring or by the pressure casting method.

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The structure and mechanical properties of Stellite-type alloys are considerably affected by cooling rate and material of molds. Rapid cooling results in the formation of a fine-crystalline structure which provides for improved mechanical properties. Coarse structure and, consequently, lower mechanical properties are caused by slow cooling.

Two methods are used for hard surfacing: oxyacetylene welding in reducing flame, and electric-arc welding by the Slavyanov method.

The first method secures a better quality of welded hard-facing deposits without mixing with base metal. Electric-arc hard facing of Sormayt by the Slavyanov method is conducted with the Sormayt electrode coated with a compound made of fluorspar, ferromanganese, ferrochromium, aluminum powder, graphite, and marble mixed in water glass. The structure of Sormayt is very little affected by the method of welding. The hard-facing deposit consists of the solid solution of chromium in iron and of the carbide eutectic, with complex carbides for Sormayt No 1 and without them for Sormayt No 2.

Powder Hard Alloys

Two powder alloys, Vokar and Stalinit, are manufactured in the USSR. They have the following chemical composition:

	W	Cr	C	Mn	Si	Fe
Vokar	$\geq$ 86	-	9.5-10.5	-	0.5 max	2.5 max
Stalinit	-	16-20	8-10	13-17	3 max	Remainder

Vokar is made of powdered metallic wolfram, and materials for Stalinit include ferromanganese, ferrochromium, cast-iron chips, and petroleum coke. Initial materials after ball milling are carefully mixed with sugar (Vokar), or molasses (Stalinit), and boiled at 400°C with continuous stirring until the mixture is thick and dark. After cooling and crushing, the mixture is roasted in cast-iron pots.

Vokar differs very little from Stalinit in appearance, but its specific gravity is almost twice as great as that of Stalinit. Hard-facing deposition of powder hard alloys is usually attained by carbon-arc welding.

The facing deposit of Vokar represents a compound of complex wolfram-iron carbides and wolfram carbides and the deposit of Stalinit consists of complex chromium-manganese-iron carbides with presence of these complex carbides in the free state.

In case of double-layer deposition of Vokar, the hypereutectic structure with angular segregations of carbides and wolframides is obtained.

Double deposition of Stalinit results in the hypereutectic structure with needle-like carbides in a matrix of fine carbide eutectic.

Vokar and Stalinit form deposits not compact and sometimes with small surface cracks. A more compact fused deposit may be obtained by preheating parts to be hard faced. Rockwell hardness (A scale), of Vokar is 80-82 and hardness of Stalinit amounts to 76-78. Wear resistance of Vokar deposits is higher than that of Stalinit. Melting temperature of Vokar is 2,700°C, and of Stalinit, 1,300-1,350°C. The hardness of a welded deposit of Stalinit remains unchanged in heating to 500° but sharply decreases on further increase of temperature. The welded facing layer of Vokar has a higher red hardness than that of Stalinit.

After heat treatment of the welded layer of Stalinit, its hardness increases by 8-10%.

Metalloceramic Hard Alloys

A prototype of these alloys, the German composite, Widia, appeared in 1925. In the USSR the first metalloceramic alloy, Pobedit, was manufactured in 1929. Its composition is 90% wolfram carbides and 10% cobalt.

Since 1933, a special technology with chemical deposition of the cementing metal has been used for manufacturing metalloceramic alloys (alloy RE-8 with 8% cobalt). Later, the alloys of wolfram and titanium carbides with cobalt were developed, namely: Pobedit alpha-15 (A-15), and Pobedit alpha-21 (A-21), used intensively in machine building. Wolfram carbide-nickel alloys are known as Reniks 6 (REN-6), Reniks 8 (REN-8), and others.

Several alloys of local or special significance are also produced in the USSR. Some of these are: Sergonit, which, in its chemical composition approaches alloy T15K6; Bikar, which is close to alloy VK8; and Dolotit, a complex titanium-chromium carbide used in the petroleum industry. The red hardness of metalloceramic alloys, i.e., their ability to retain hardness at elevated temperatures, may be expressed in °C as follows:

Pobedit with 10% Co	900°C
VK6 (RE-6)	1,000
VK8 (RE-8)	900
VK12 (RE-12)	800
VK15 (RE-15)	700
T21K8 (A-21)	850-900
Sergonit	900-950

Coefficients of thermal expansion α for the range 20 to 800°C and thermal conductivity λ in cal/cm-sec-degree are determined:

	α	λ
For wolfram-carbide alloy with 6% Co	$5 \cdot 10^{-6}$	0.19
Same with 11- Co	$5.5 \cdot 10^{-6}$	0.16
For titanium-wolfram carbide alloys of T5K6 type	$6 \cdot 10^{-6}$	0.14
Same of T15K6 type	$6 \cdot 10^{-6}$	0.09

Wear resistance, i.e., loss of weight in mg/sq mm, determined in testing on carborundum wheel for the same period of time is as follows:

Alloys VK6, VK8, T21K8, and Sergonit	0.4-0.5
Pobedit with 10% Co	0.5-0.6
VK12	0.6-0.7
VK15	0.7-0.8

The following types of metalloceramic hard alloys are used in the USSR: wolfram carbide with cobalt, VK3, VK6, VK8, VK12, formerly designated as RE-3, RE-6, RE-8, RE-12, wolfram carbide with nickel, VN6, formerly designated REN-6; titanium carbide and wolfram carbide with cobalt, T5K6, T15K6, T5K10, T21K8 formerly designated A-5, A-15, A-10, and A-21.

Basically, the process of manufacturing metalloceramic alloys consists of pressing the mixture of fine powder of wolfram carbide with binder, cobalt or nickel powder, into molds and sintering at a temperature near the melting point of the binding metal. Partial or complete melting, depending on the amounts of WC and Co, takes place in the sintering process. The resultant product represents a very compact, hard alloy comprised of carbides cemented with a solid solution of the carbides in cobalt or nickel.

The structure of wolfram-cobalt alloys consists of two components: carbide of wolfram and solid solution of wolfram carbide in cobalt. Wolfram-titanium-cobalt alloys have a more complex structure comprised of wolfram and titanium carbides and solid solution of these carbides in cobalt.

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The size of crystals forming a hard alloy depends on the granularity of initial powders, temperature, and length of sintering.

Overheating in the sintering process, heating wolfram-alloys above 1,500°C and wolfram-titanium alloys above 1,550°C, promotes crystal growth and impairs the mechanical properties of alloys.

The quality of an alloy may be evaluated by the appearance of its fracture: a uniform porcelain—like fracture is considered a normal fracture; the coarse-grain fracture characterizes an overburned alloy; the cracked fracture indicates lamination of an alloy in the process of its preparation; a dark color shows poor sintering of alloys and also indicates the presence of free carbon in alloys (cf appended table 1).

Cast High-Carbide Hard Alloys (cf appended table 2).

This group of alloys represents the fused carbides of high-melting metals. Most used is the carbide of wolfram, sometimes with a small addition of titanium of molybdenum. Fused carbides of wolfram form an eutectic of WC and W_2C. In comparison with other types of hard alloys, cast high-carbide alloys are more brittle. They are utilized predominantly in the petroleum industry (Relit, Likar).

Tubular or Crushed Hard Alloys

These alloys consist of crushed hard alloys in the form of grit or small lumps, which are packed in steel or iron tubes.

Hard-facing deposition of these alloys may be done with an oxyacetylene blowpipe or with electric arc by the Slavyanov method. The first welding method is preferable.

The welding of edges to cutting tools may be executed by two methods: with melting of the metal of the tube only or with simultaneous melting of the grit of hard alloy packed in the tube. In the first case, the crushed particles are welded to the base metal and serve as the cutting edge of the tool. In the second case, an alloy is formed, representing a solid solution of carbides in iron. Tubular alloys are used mostly in the petroleum industry.

Electrode Hard Alloys

These alloys are in the form of electrodes made of wire with ferrochromium and ferromanganese coating, which also includes graphite, chalk, and water glass. The thickness of the coating layer may be 0.8-1.5 mm depending on the diameter of the electrode. The process of hard facing results in deposition of a hard and wear-resistant layer due to the formation of complex carbides of manganese or chromium in iron. Alloys of this group are used for hard facing the parts of road building machines, dredging shovels, and others.

Table 1. Composition and Physicomechanical Properties of Metalloceramic Alloys Used for Manufacturing Tips of Cutting Tools

	Approx comp (%)				Bending Strength (kg/sq mm)	Sp Gr	Rockwell Hardness (A scale)
Alloy	WC	TiC	Co	Ni	Minimum		
VK3	97	-	3	-	-	14.85	89.0
VK6	94	-	6	-	120	14.5	87.5
VK8	92	-	8	-	130	14.3	87.5
VK12	88	-	12	-	150	14.1	86.5
VN6	94	-	-	6	100	14.65	87.5
T5K6	89	5	6	-	80	12.4	88.0
T15K6	79	15	6	-	80	12.2	87.5
T5K10	85	5	10	1	80	10.9	88.0
T21K10	71	21	8	-	80	10.0	88.0

Table 2. Composition and Physicomechanical Properties of Hard Alloys Used for Manufacturing Wire-Drawing Dies

Alloy	Approx comp (%)		Bending Strength (kg/sq mm)	Sp Gr	Rockwell Hardness (A scale)
	WC	Co		M i n i m u m	
VK6	94	6	120	14.5	87.5
VK8	92	8	130	14.3	87.5
VK10	90	10	130	14.2	87.0
VK13	87	13	140	13.9	86.5

Table 3. Etching Reagents for Microscopic Examination of Hard Alloys

Etching Reagent	Application	Structure Revealed
Kurbatov's reagent 5% picric acid 40 ml 30% sodium hydroxide 60 ml	Metalloceramic and cast high-carbide hard alloys	Crystals of carbides (darkened)
Yatsevich's reagent Hydrogen peroxide 10 ml 10% solution of sodium hydroxide in 20 ml of water	Same	Crystals of wolfram carbides (darkened)
Murakami's reagent $K_3Fe(CN)_6$ 10 g Potassium hydroxide 10 g Water 100 ml	Stellites and stellite-like alloys. Electrode and powder hard alloys	Carbides are darkened
Aqua regia Hydrochloric acid 2 g Nitric acid 1 g Glycerin 36 g	Same	Primary carbides and carbides of the eutectic remain uncolored, the solid solution of the eutectic is darkened
Hydrofluoric acid 1 g Nitric acid 3 g	For all hard alloys	Same

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